

Appendix

Psychometric Analysis of the Thermochemistry Concept Inventory

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Potential Users of the TCI

Chemistry instructors and chemical education researchers interested in using the finalized version of the Thermochemistry Concept Inventory (TCI) should contact the corresponding author for an electronic copy. In addition to the finalized version, a detailed answer key has been made for use in formative assessment, to provide students detailed explanations why each distracter is incorrect and what associated alternative conception is associated with each incorrect answer.

Additional Psychometric Evidence

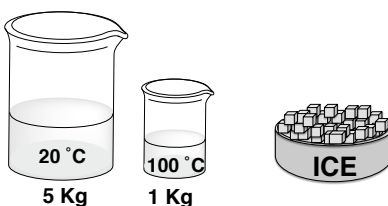
For each of the 10 items on the Thermochemistry Concept Inventory, a full set of quantitative data is presented.

Data presented includes:

- 1) The item itself
- 2) Item response frequencies and Rasch ability levels
- 3) Rasch difficulty measure values
- 4) Rasch Item option probability curves

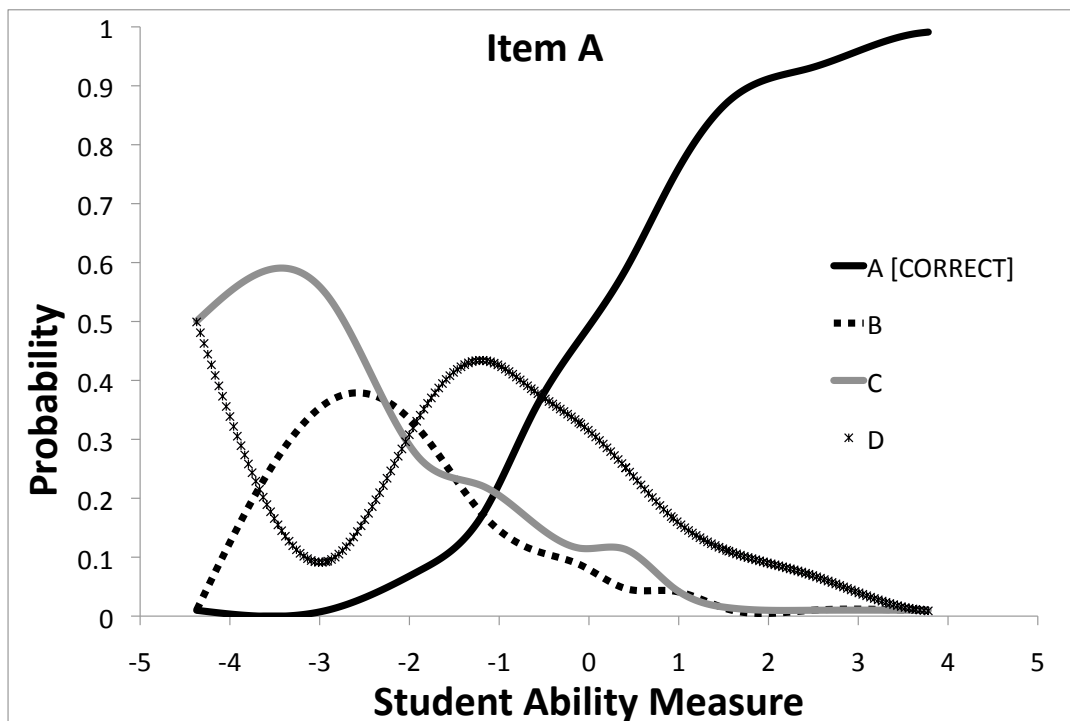
Item A

Two beakers of differing volumes contain pure water at different temperatures. Ice is added to the water in each beaker. Choose the most accurate answer given below.



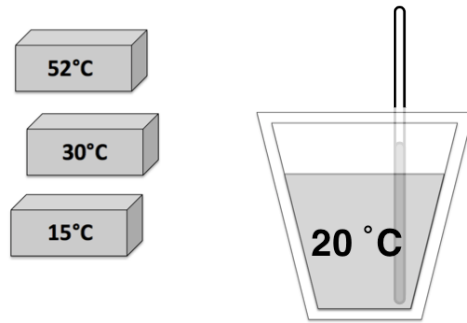
- (A) Equal amounts of ice will melt in each beaker
- (B) The water is considered the system because it is giving off heat
- (C) The melting of the ice in either container is considered an exothermic process
- (D) More ice will melt in the beaker with water at 100 °C

Item A			
Item Option	Count	%	Rasch Average Ability
A	706	55	0.82
B	101	8	-0.39
C	142	11	-0.29
D	343	27	0.02
Rasch Difficulty Measure			0.16



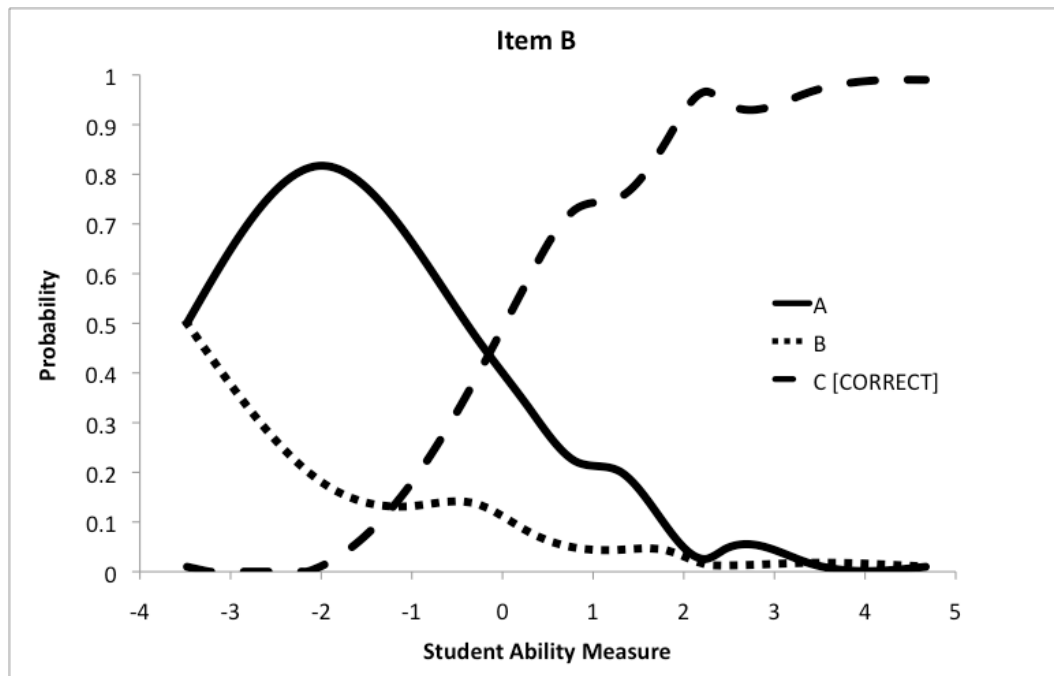
Item B

A styrofoam coffee cup contains water at 20 °C. Three identical metal blocks at three different temperatures are shown to the left of the cup. Choose the most accurate response below.



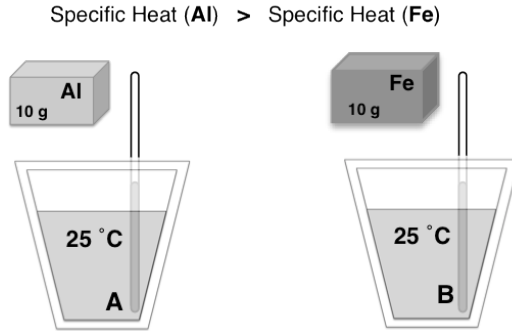
- (A) When the block at 30 °C is added to the water, thermal energy will flow back and forth between the block and the water until thermal equilibrium is reached
- (B) When the block at 52 °C is added to the water, the system would be defined as everything in the coffee cup and the surroundings would be everything else
- (C) When the block at 15 °C is added to the water, the process can be described as an endothermic process with respect to the block

Item B			
Item Option	Count	%	Rasch Average Ability
A	286	22	-0.28
B	75	6	-0.20
C	930	72	0.64
Rasch Difficulty Measure			-0.74



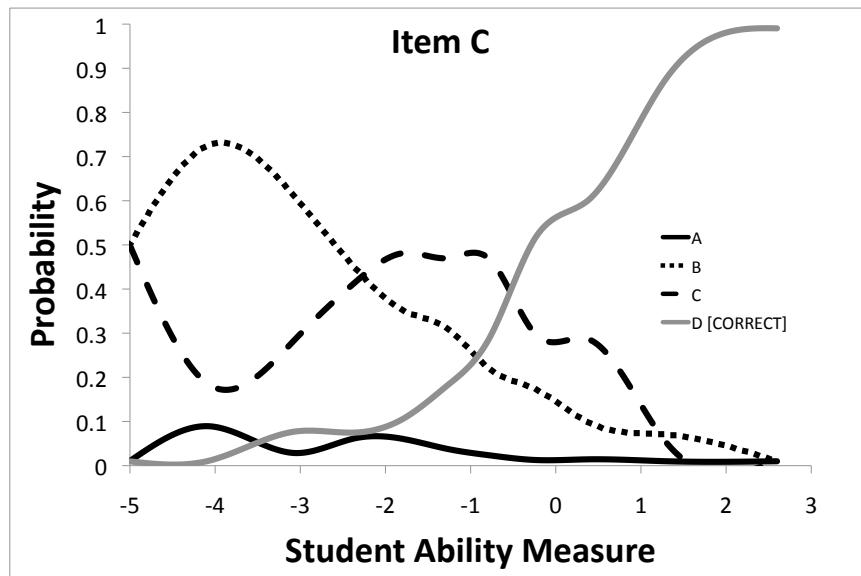
Item C

A block of Aluminum (Al) and a block of Iron (Fe) each at 50 °C are simultaneously dropped into identical styrofoam cups containing the same amount of water at 25 °C water. Choose the most accurate answer given below.



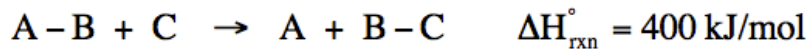
- (A) After adding either block to the water, the process can be described as an endothermic process, with respect to the block
- (B) Thermal energy will be transferred faster between the Al block and the water than between the Fe block and the water
- (C) The final temperature of the water in both A and B will be the same
- (D) The water in A will have a higher final temperature than the water in B

Item C			
Item Option	Count	%	Rasch Average Ability
A	41	3	-0.11
B	343	27	-0.10
C	513	40	0.22
D	395	31	1.09
Rasch Difficulty Measure		1.37	



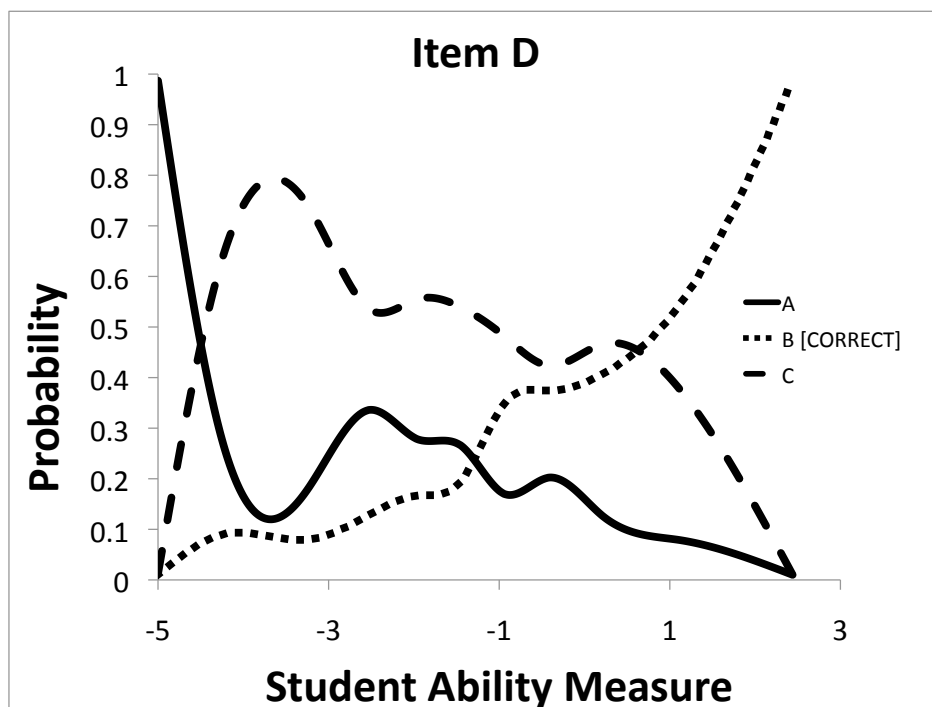
Item D

Use the following reaction and the associated standard reaction enthalpy to choose the most accurate answer below.



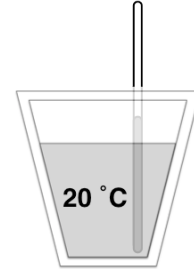
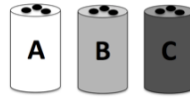
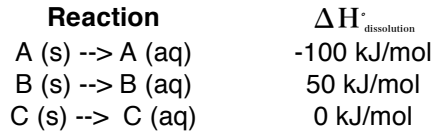
- (A) The breaking of the A-B bond is exothermic and the making of the B-C bond is endothermic
- (B) The bond enthalpy (energy) of the reactants is larger than the bond enthalpy (energy) of the products
- (C) The reaction requires 400 kJ/mol of energy to occur

Item D			
Item Option	Count	%	Rasch Average Ability
A	282	22	0.11
B	365	28	0.84
C	644	50	0.26
Rasch Difficulty Measure			1.51



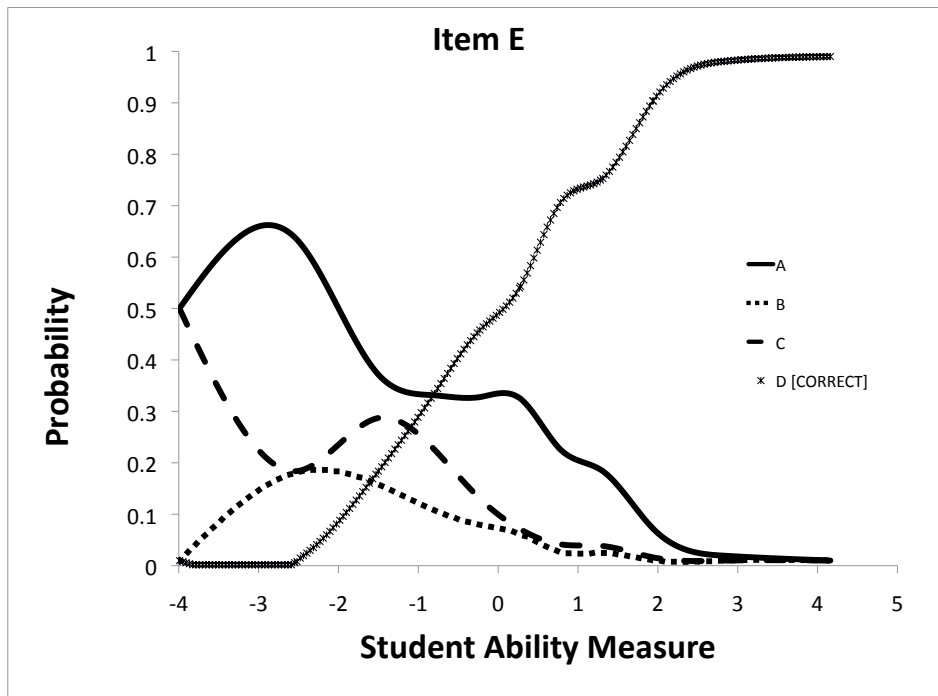
Item E

A styrofoam coffee cup contains water at 20 °C. Three salt shakers are shown below, containing salts A, B & C. Use the reaction enthalpies given to choose the answer that most accurately describes what would happen when equivalent moles of salt are added to the water.



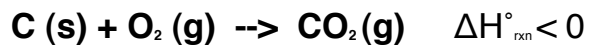
- (A) When salt A is added to the water, heat is created
- (B) When salt C is added to the water, it will not dissolve
- (C) The temperature of the water in the cup will increase when salt B is added
- (D) Adding salt A will result in the largest change in temperature

Item E			
Item Option	Count	%	Rasch Average Ability
A	319	25	-0.03
B	65	5	-0.32
C	103	8	-0.41
D	804	62	0.71
Rasch Difficulty Measure			-0.22



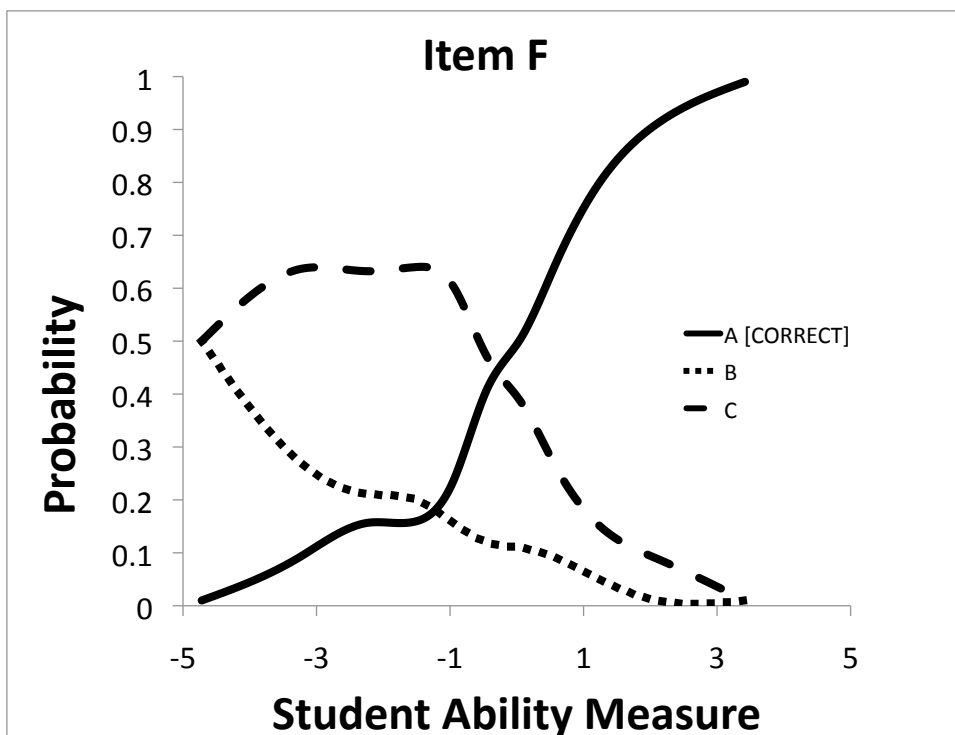
Item F

The production of carbon dioxide from elemental carbon and oxygen is shown in the reaction below. For this reaction, choose the most accurate statement below.



- (A) The product is more energetically stable than the reactants
- (B) The production of $\text{CO}_2(\text{g})$ is an endothermic process
- (C) The change in enthalpy of the reaction depends on the amount of heat contained in the reactants and product

Item F			
Item Option	Count	%	Rasch Average Ability
A	609	47	0.85
B	153	12	-0.05
C	529	41	-0.02
Rasch Difficulty Measure			0.52



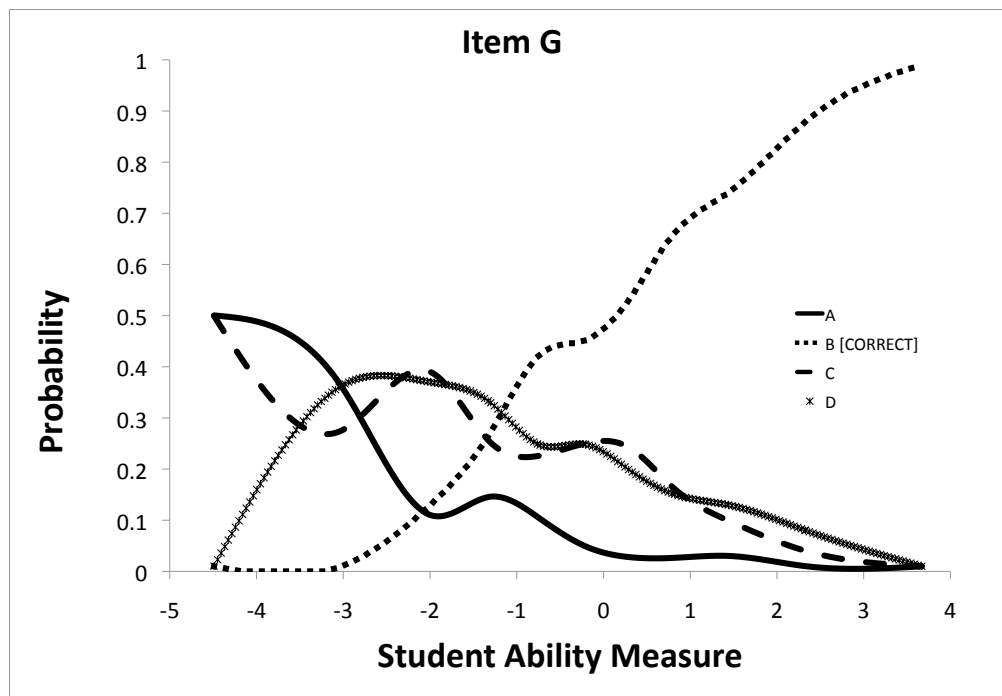
Item G

Use the chemical equations below to choose the most accurate response. Each chemical equation represents the formation of a molecule from elements in their standard state.

Reaction	Equation	$\Delta H_{\text{rxn}}^{\circ}$
[1]	$A(g) + B(g) \rightarrow AB(g)$	-100 kJ/mol
[2]	$C(g) + D(g) \rightarrow CD(g)$	-500 kJ/mol

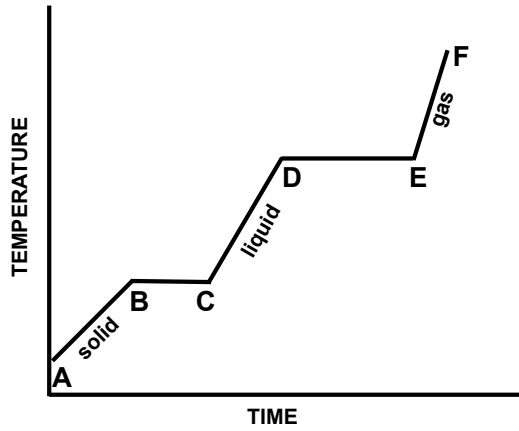
- (A) Reaction [2] will reach completion faster than reaction [1]
 (B) The bond energy for AB (g) is less than the bond energy for CD (g)
 (C) Based on the $\Delta H_{\text{rxn}}^{\circ}$ values, neither reaction requires energy to occur
 (D) Reaction [1] is more endothermic than reaction [2]

Item G			
Item Option	Count	%	Rasch Average Ability
A	75	6	-0.37
B	674	52	0.72
C	270	21	0.08
D	273	21	0.07
Rasch Difficulty Measure			0.28



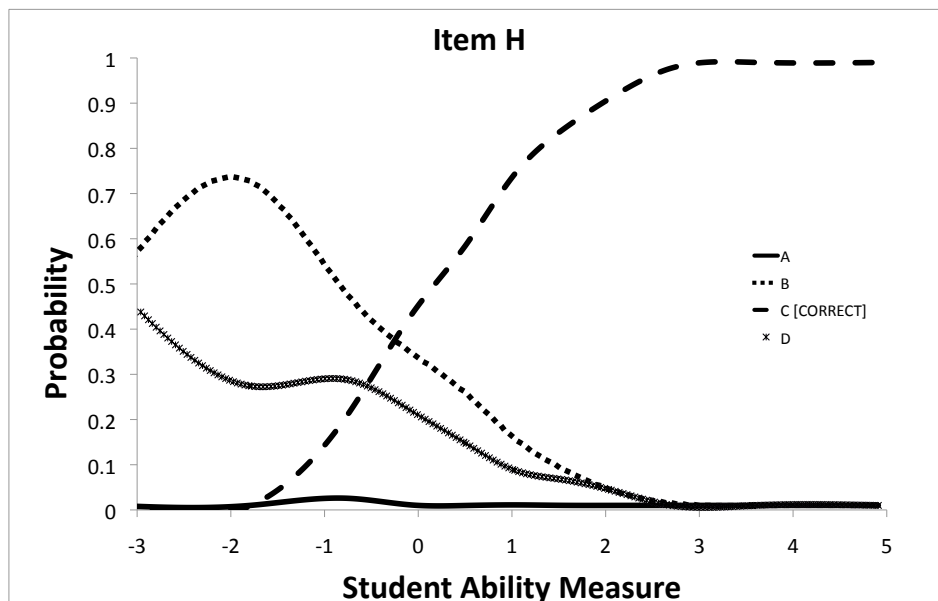
Item H

Using the heating curve for water provided, select the most accurate answer.



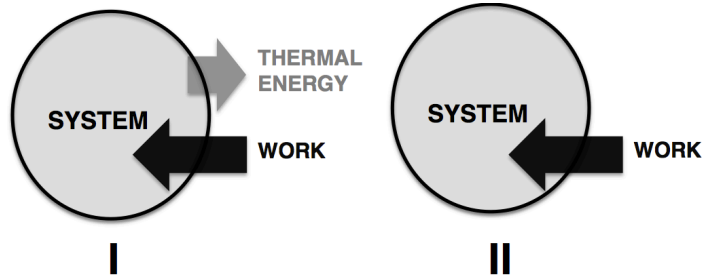
- (A) The Y-axis of this graph could also be labeled as *heat*, because temperature and heat are the same
- (B) Moving from point D to E temperature is constant, therefore no thermal energy is added
- (C) The freezing of water, represented by moving from C to B, is an exothermic process
- (D) The water at point C is a liquid, therefore the temperature cannot be 0 °C

Item H			
Item Option	Count	%	Rasch Average Ability
A	6	0	-0.40
B	192	15	-0.44
C	976	76	0.65
D	118	9	-0.36
Rasch Difficulty Measure			-0.96



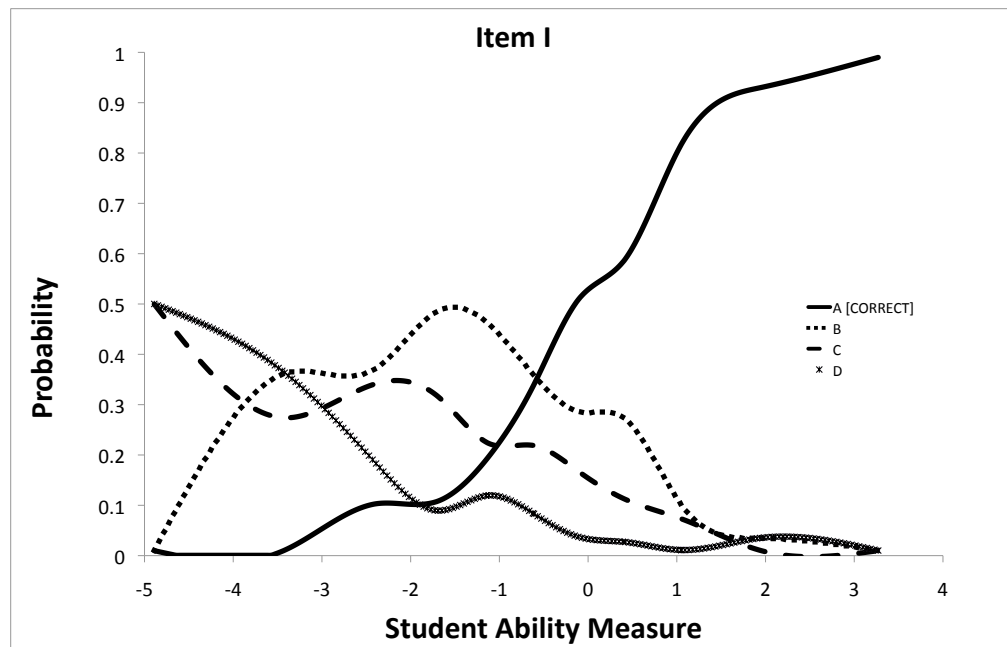
Item I

Two identical systems I and II are shown below. The direction and magnitude of thermal energy transfer and work are represented by arrows. Use this information to choose the most accurate response below.



- (A) The total energy (internal energy) for system I will increase
- (B) The temperature of system I will decrease
- (C) The process shown in system II can be described as endothermic
- (D) The sign of the work with respect to system II is negative

Item I			
Item Option	Count	%	Rasch Average Ability
A	568	44	0.93
B	408	32	0.04
C	228	18	-0.07
D	87	7	-0.30
Rasch Difficulty Measure		0.68	



Item K

If a reaction has a **positive** reaction enthalpy (ΔH_{rxn}), choose the most accurate response below.

- (A) The reaction can be described as an **exothermic** process
- (B) The reaction can be described as an **endothermic** process
- (C) There is **NOT** enough information to determine if the reaction is an exothermic or endothermic process

Item K			
Item Option	Count	%	Rasch Average Ability
A	55	4	-0.48
B	1200	93	0.43
C	37	3	0.32
Rasch Difficulty Measure		-2.60	

